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ABSTRACT

The mathematics education reform movement is built on ideas about the nature of learning, teaching, and indeed mathematics itself that are very different from the views that have prevailed in American schooling for many years. This has implications for administrative practice, since an enterprise that exists to support rigorous thinking on the part of students requires administrative supports different from those for approaches that exist to transmit accepted knowledge from teacher or textbook to student. Understanding new ideas about mathematics, learning, and teaching, and exploring the implications of these ideas for administrative practice require conceptual change on the part of many administrators. This paper describes the pedagogical principles that underlie a program designed to provide opportunities for such conceptual change for administrators. (Contains 48 references.) (Author)

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January 1999

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Building New Knowledge by Thinking: How Administrators Can Learn What They Need to Know About Mathematics Education Reform

Barbara Scott Nelson

The mathematics education reform movement is built on ideas about the nature of learning, teaching, and indeed mathematics itself that are very different from the views that have prevailed in American schooling for many years. This has implications for administrative practice, since an enterprise that exists to support rigorous thinking on the part of students requires administrative supports different from those for approaches that exist to transmit accepted knowledge from teacher or textbook to student. Understanding new ideas about mathematics, learning, and teaching and exploring the implications of these ideas for administrative practice require conceptual change on the part of many administrators. This paper describes the pedagogical principles that underlie a program designed to provide opportunities for such conceptual change for administrators.

The mathematics education reform effort currently under way suggests that children, teachers, and administrators develop deeper and more considered ideas about what mathematics learning and indeed the intellectual character of school more generally might be. That is, the very ideas about the nature of learning, teaching, and mathematics on which typical educational practice has long been based are changing. Rather than viewing (1) mathematics learning as the absorption of a series of facts and mastery of procedural manipulations and (2) teaching as the provision of conditions for absorption and practice (here called the "transmission" view), teachers and children are now meant to view mathematics as a subject that can be reasoned out and make sense. Reformers want mathematics classrooms to function as mathematical communities in which students have opportunities to reason mathematically, communicate about mathematical ideas, and make connections among mathematical ideas and between mathematics and their own daily lives (here called the "socioconstructivist" view).

Both teachers and children have begun to reconstruct their sense of the learning and teaching enterprise, and consequently what their

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work together is. These shifts in meaning and practice have been well documented for teachers (cf. Fennema & Nelson, 1997; Franke et al., 1997; Schifter, 1996a, 1996b; Schifter & Fosnot, 1993) and to some degree for children (Cobb et al., 1992; Lester, 1996; Soucy-McCrone, 1997). The possibility that similar changes in belief and practice are indicated for school and district administrators is beginning to be investigated (Nelson, 1997; Spillane & Halverson, 1998; Spillane & Thompson, 1997), and there is an emerging body of research on the ideas that administrators construct about the reforms (Nelson, 1997; Nelson & Sassi, 1998; Spillane, 1998).

However, professional development programs for administrators that provide support as they work to understand reform ideas are just beginning to appear. It is the premise of the work described in this paper that such programs need to provide administrators with the opportunity to explore new ideas about mathematics, learning, and teaching, but that they also need to address the fit between ideas of school administration and ideas about learning and teaching. That is, there is a mismatch between the principles that underlie much educational administration and the principles that underlie reformed mathematics instruction. To manage reformed instruction effectively, administrators need to reexamine both their ideas about mathematics, learning, and teaching and their ideas about school management.

Some forms of instructional management are aligned with transmission forms of instruction; other forms align better with reformed instruction. For example, bureaucratic forms of management and control assume, with transmission views of teaching and learning, that students are sufficiently standardized that they will respond to instruction in predictable ways, that teaching tasks are routine enough to be converted to procedures, and that classrooms can be viewed as similar, self-contained units to be organized by a common schedule and common rules (Campbell et al., 1987; Rowan, 1990). Entire lines of research and practice in the management of instruction have been built on the transmission view of learning and teaching: direct instruction in basic skills as one of the hallmarks of effective schools (Edmonds, 1979), process-product research on teaching (Brophy & Good, 1986), and the consequent processes of teacher supervision (Darling-Hammond & Sclan, 1992). Other administrative practices, such as those deriving from human relations theories of management (Campbell et al., 1987), community metaphors for schooling (Sergiovanni, 1994), or views of administrators as learners (Barth, 1990), are more likely to emphasize the relationships between professional colleagues in a school and the growth of individuals than the standardized delivery of instructional services.

When fundamental ideas about learning and teaching that form the center of the enterprise of schooling begin to shift, as now, the eclectic array of existing management ideas and practices is thrown into relief. Inconsistencies between what is being managed and the nature of the management become more apparent, and consideration of what administrative practices are now most appropriate becomes relevant (Rowan, 1995; Sykes, 1995). It is also possible that in the effort to support new modes of teaching and learning, new administrative practices will emerge.

The disjunction between what is being managed and the models available for management is not just an abstract matter; it plays out in the ideas and daily actions of many school and district administrators. Most administrators were educated at a time when the transmission view of learning and teaching prevailed. Their personal teaching histories, often based on this view, inform their administrative practice. Administrators have specific images of classrooms, teaching, and learning in mind as they make administrative decisions that they intend as supportive. These images, along with the images of management that they have acquired over the years, ground their sense of *what* it is that is being managed and *how* it can be supported.

To make this connection clear, consider the example of teacher evaluation. Many administrators have images of mathematics classrooms in which the lesson is presented, students do work at their seats or in groups, and homework is assigned, with the expectation that the lesson should be tied up neatly by the end of the class

period—the facts of the lesson and the homework assignment clear. This image of classrooms is based on the notions that knowledge can be unproblematically transmitted from teacher or textbook to students in discrete chunks that can fit neatly into a 42-minute class period and everyone's mind can then shift cleanly to the next subject on the agenda. Such an image leads many principals evaluating a teacher's performance to expect "closure" to the lesson. But evaluating classrooms in which knowledge unfolds through discourse and in which interesting questions are not all answered by the end of the class period requires a different image of what knowledge is and therefore what should go on in classrooms and how the lesson might end. Traditional notions of closure may be inappropriate. Administrators whose expectations of how a lesson should end are based on a transmission view of learning will be out of alignment with contemporary ideas about inquiry- or discourse-based teaching and are likely to perform the administrative function of teacher evaluation in a way not attuned to the intent of that teaching. One principal with whom we have worked described how his expectation for closure to lessons changed:

> From a traditional observation's point of view and a paradigm of the past, most principals, I assume, would go in and look for a total lesson, that the closure would be there . . . that you wouldn't leave any cliff hangers to be carried over. [In the lesson on this videotape] there's a shift to saying, "I'll carry it on another day." Kids go home and do their follow-up assignment. . . . I look for closure in most lessons and I'm not seeing [it] any more and it doesn't upset me as it would [have] in the past.

This is not to say that there is now no sensible way for lessons to end, only that the traditional idea of closure may be inappropriate for a classroom environment in which important and hard ideas are being discussed over a long period. "Closure" may need to be redefined.

A premise of our work with administrators is that their ideas about the nature of learning and teaching matter. That is, if one is responsible for administering a school or school district, it is not sufficient to employ management techniques without regard to the degree to which they are appropriate to the nature of the processes being administered. Understanding the nature of the organization's basic processes—in this case, teaching and learning—is a prerequisite for appropriate management.[1] And so, in our view, it is necessary for administrators to understand contemporary ideas about the nature of learning and teaching in order to take a critical stance toward their own administrative practice and modify it where appropriate.

In this paper, I will first describe the context and theoretical underpinnings of the work my colleagues and I did with school and district administrators on the ideas of mathematics, learning, teaching, and management. Three pedagogical design principles for this work—which took the form of a monthly seminar—are identified. I then present three vignettes that show the design principles at work. I use each vignette to illustrate the nature of one of the pedagogical design principles, the kind of conceptual change it supports, and the relation between new educational ideas and issues of management.

Methodology

Context

To understand how administrators' ideas about learning, teaching, and mathematics affect their work and to explore the possibility that they might ground their administrative practice on new and different ideas about the nature of learning and teaching, we worked for three years with a group of administrators who were interested in developing a deeper understanding of mathematics education reform and in considering its implications for their work. Forty school and district administrators from districts in metropolitan Boston, including Boston, participated in the program: 32 elementary school principals, 5 district-level elementary mathematics coordinators or supervisors, and 3 assistant superintendents of curriculum and instruction. While the total enrollment was 40, administrators participated for the years during which teachers from their schools took part in a related teacher enhancement program. Therefore, total administrator enrollment each year was about 20. On average, 15 administrators were in attendance at any given monthly meeting. Most administrators participated for two years, seven participated for three.

Of the group, one was concurrently a high school mathematics teacher. The others had little formal mathematics training; the elementary principals would have taught mathematics as part of their elementary school teaching experience. Two had Ph.D. degrees in liberal arts subjects; most had master's degrees in education. All had been administrators for at least 5 years; many, for 20 or more.

While a few of the administrators in the group consistently expressed views that indicated a transmission perspective on learning and teaching, most held mixed positions—combinations of transmission and socioconstructivist views. Two administrators consistently expressed ideas about the development of children's knowledge that could be characterized as socioconstructivist and had for many years participated in professional associations that supported these views.

We and the administrators explored the ideas about learning, teaching, and mathematics that underlie the mathematics education reform effort and related them to specific areas of administrative practice of concern to the administrators. We did this work through a monthly seminar, or "inquiry group," for which project staff assigned readings, developed activities, and facilitated group discussions to give administrators the opportunity to more deeply examine their fundamental ideas about mathematics, learning, teaching, and the intellectual culture of schools. Project staff intended these discussions to encourage administrators to articulate and examine their own understandings of learning, teaching, mathematics, and school culture—ideas that for many administrators functioned as assumptions and were no longer critically examined. The project's goal was to promote administrators' reflection on the degree to which those ideas were helpful guides for practice in the current reform climate.

Data collection and analysis

Ethnographic field notes were taken at all administrator inquiry group meetings. These meetings were also audiotaped, and the tapes were transcribed. In-depth interviews were conducted with all administrative participants at the beginning and end of the program. These interviews were audiotaped and transcribed.

The data analyzed for this paper consisted of the planning notes for all seminar meetings, transcriptions of the audiotapes of seminar meetings, and transcriptions of all interviews with administrators. Seminar planning notes were reviewed to identify the major design principles that underlay the work. This resulted in the identification of three primary design principles. Seminar sessions in which those principles were particularly well illustrated were identified. Transcripts of those sessions were analyzed to identify events that could serve as vignettes for this paper.

Pedagogical Design to Support Administrator Learning

For many administrators, developing new ideas about learning, teaching, and mathematics entails fundamental conceptual changes (Nelson, 1997). In particular, most of the administrators in the group we were working with viewed learning, teaching, and mathematics in transmission or mixed ways, and therefore the opportunity to think through these ideas, as represented in mathematics education reform, was indicated. While there is little research on conceptual change on the part of administrators prompted by the discipline-based reform movement, there is substantial literature about the conceptual changes required of teachers (e.g., Carpenter, Fennema, Peterson, & Carey, 1988; Fennema et al., in press; Lampert, 1987; Schifter & Fosnot, 1993; Schifter & Simon, 1992; Thompson, 1991; Wasley, 1990). As a starting point for our work with administrators, we adapted the theoretical position that underlies our work with teachers, which is designed to provide opportunities to explore transmission and socioconstructivist ideas about learning, teaching, and mathematics (Nelson & Hammerman, 1996; Schifter & Fosnot, 1993; von Glasersfeld, 1990).

When working with teachers, we are very aware that, by and large, they have been the recipients of the traditional form of mathematics education that is currently under revision. Therefore, they need opportunities to experience mathematics differently, to deepen their mathematics knowledge in ways that will strengthen their teaching, and to consider new ideas about how children's mathematical thinking develops. All

of these will have an impact on what and how teachers teach. Moreover, just as we now know that children do not develop mathematical understanding solely by being told mathematical facts and practicing mathematical procedures, neither do teachers develop new ideas about mathematics, learning, and teaching simply by being told new facts and practicing new techniques. In our experience, teachers learn best by actively working on intellectually interesting mathematical and pedagogical problems, resolving dissonances between the way they initially understood the situation and new evidence that challenges that understanding, and developing new understandings of mathematical and pedagogical ideas (Nelson & Hammerman, 1996; Schifter & Fosnot, 1993). As Thompson and Zeuli so compellingly put it in the context of student learning,

> Such thinking is generative. It literally creates understanding in the mind of the thinker. Thinking is to a student's knowledge as photosynthesis is to a plant's food. Plants don't get food from the soil. They make it through photosynthesis, using nutrients and water from the soil and energy from sunlight. No photosynthesis, no food. Students don't get knowledge from teachers, or books, or experience with hands-on materials. They make it by thinking, using information and experience. No thinking, no learning. At least, no conceptual learning of the kind reformers envision. (Thompson & Zeuli, 1997, p. 9)

In planning our work with administrators, we took it as our task to determine how to provide the contexts in which administrators could build new knowledge by thinking—new knowledge about mathematics, about learning, about teaching, about their own administrative practice.

We expected that administrators' learning about (1) mathematics and (2) children's thinking about mathematics would be similar to teachers'. However, administrative work has a relation to children's mathematical thinking that is different from that of teaching. Teachers have the opportunity to observe student thinking every day in their classrooms, reflect on what they see, and base the next teaching move on an assessment of what their students might productively think about next. Teachers' work is very close to and intertwined with students' thinking. Administrators' work is distanced from the classroom, and it was not clear at the outset how ideas about mathematics and children's mathematical thinking could be made relevant to administrators' own work, nor how aspects of their administrative practice might change once administrators' ideas about the nature of mathematics, learning, and teaching began to change.

In this paper, I sketch out three aspects of the design of our work with administrators that we feel are fundamental in helping administrators think deeply about learning, teaching, and mathematics, and consider the difference to their administrative practice of grounding it in new views. Each addresses the relationship between the ideas of mathematics, teaching, and learning embedded in mathematics education reform and administrators' work in a subtly different way. Together they offer a powerful opportunity for administrators to think through the relationship between educational ideas and administrative ideas.

The first design principle, called "layering," is a structure for the seminar as a whole and for individual sessions that points out the direct links between children's mathematical thinking, teachers' mathematical and pedagogical thinking, and administrators' thought and practice. This structure enables administrators to consider the possibility that reformed mathematics classrooms have norms, values, and practices that might be valuable for the school as a whole and therefore for their own administrative practice.

The second design principle is to situate the conceptual work of thinking about mathematics, learning, and teaching in areas of administrators' own work. That is, new ideas about mathematics, learning, and teaching affect not only the nature of instruction but also administrative functions that are related to instruction—classroom observation and teacher supervision, curriculum adoption, selection of student assessment instruments, communication with community stakeholders, and so on. Thinking about new ideas in the context of these administrative tasks motivates administrators to do the hard work of reconceptualizing fundamental ideas.

The third design principle is to operate the seminar according to the pedagogical principles that inform reformed mathematics classrooms. This gives administrators the opportunity to directly experience "thinking in order to learn" for themselves and to analyze together what has happened in the seminar to make such learning possible. Implementing this design principle has many ramifications, only two of which are discussed here: (1) doing mathematics together and (2) functioning as an analytic and reflective community.

These design principles are not mutually exclusive—that is, most sessions of the inquiry group were layered, grounded in an area of practical action, and functioned as an analytic and reflective community. The distinction made here is analytic. More than one design principle can be seen in each of the vignettes below.

Design Principles

Layering

If administrators are to consider the possibility that the mathematics education reform effort implies a very different intellectual culture for schools and different behavior on their part, they need opportunities to explicitly think about how central elements of this new culture would be enacted at different organizational levels, including their own.

The first design principle, *layering*, is designed to provide such opportunities. In general, we constructed class sessions so that it would be possible to consider the way in which important aspects of the mathematics education reform effort would be enacted at several levels of the educational system: the level of students, the level of teachers, and the level of administrators. To illustrate what layering is and what administrators can learn from it, we describe the design of a session in which administrators were learning about "a different kind of listening."

One important tenet of reformed mathematics instruction is the need for teachers to listen carefully to students' mathematical thinking and to base their instruction on what they learn (Franke et al., 1997; Schifter & Simon, 1992). Such listening is an essential element of the move from a didactic mode of teaching to a more facilitative one. Of course, teachers also need to know enough mathematics to be able to interpret the mathematical significance of what children say, and have good ways of intervening to help children's mathematical thinking move forward. But a fundamental difference between traditional and reformed teaching is teachers' stance of listening itself. The layered session described below was designed to provide administrators with the opportunity to listen to a child's mathematical thinking, to think about what teaching would be like if it were built on knowledge of children's thinking, and to consider how the kind of respectful listening that teachers are being encouraged to do in their classrooms could be part of a new intellectual culture for the school as a whole.

Layer 1: Listening to a Child's Mathematical Thinking. Administrators watched a 17-minute video clip of a clinical interview with Genevieve, a fifth-grader. They listened to Genevieve's explanations of her mathematical thinking, not with an attitude of judgment, or searching for what needed to be fixed, but in an effort to understand the mathematical world she inhabited. They developed conjectures about what Genevieve understood, pointed to evidence that supported or disconfirmed a conjecture, and acknowledged that they were unsure about some things.

Genevieve had been asked the following question: "You have 15 cookies and there are 6 kids at your party, total. How many cookies would each child get?" Genevieve set up the standard long-division algorithm, 6)15, did the calculation, and answered, "Two and a half." Then the interviewer said, "Now, suppose your mother ate one of the cookies before she served them to you. Then there would be 14 cookies to share among you and your friends. How many cookies would each of you get, provided you were sharing equally?" Genevieve correctly executed the long-division algorithm, 6)14. She wrote the answer as 2.333 and said the answer was "two and one-third." Genevieve and the interviewer then discussed the relation between decimal and fractional representations of one-third, and Genevieve tried to represent the problem in other ways—representing the cookies in a drawing, using unifix cubes, and making

manipulatives from torn pieces of paper. In general, Genevieve had trouble making alternate representations of how the cookies would be apportioned, and trouble relating these representations to the long-division algorithm. In working on the second problem, she arrayed the "cookies" into 3 rows of 4 cookies each, with 2 left over, and spent most of her time trying to figure out what to do with the remaining 2. She did not seem to understand that the reason she had divided 6 into either 15 or 14 was that she was trying to find out how many cookies each of her 6 friends would get and therefore, in order to represent the problem with a diagram, needed to draw or make with the unifix cubes 6 piles. The problem to be solved was, How many cookies would be in each pile? Her inability to represent the problem diagrammatically indicates that while she could execute the long-division algorithm, she had only a fragile understanding of the idea of division.

In their discussion after viewing the videotape, the administrators were interested in Genevieve's perseverance and her willingness to keep exploring the problem. They talked about the trial-and-error nature of her guesses at one point, and about how she didn't seem to use her knowledge from the first problem to help her solve the second one. In general, they were struck by the difference between Genevieve's facility with the algorithm and her hesitancy and confusion when trying to explain how it worked "in cookies." They developed conjectures about this—for example, noting that she didn't seem to have an internal sense of what putting a group of things into groups really is. "So, where's the sixness?" one asked. The administrators were listening to Genevieve much as teachers listen when they are trying to understand the mathematical thinking of a child in their classroom. They were experiencing "a different kind of listening" at the first level—the level of listening to students.

Layer 2: Teaching Based on Listening. In the next part of this session, the administrators read and discussed excerpts from the journals of teachers who had done their own clinical interviews with children for the first time. At this level, administrators were exploring what it meant for teachers to engage in "a different kind of listening" and the impact that such listening was likely to have on their ideas about teaching.

The teachers had been asked to write about what was powerful for them in the experience of listening to children's mathematical thinking. Sample excerpts from their journals included:

> I was most struck by how much I learned about what [the child] knew. I had him as a student and had no idea about his system of thinking . . . or his conception of zero, or even which numbers he "liked." The wealth of information I learned is amazing to me, once I know the right questions to ask. It never occurred to me to ask a child how they knew that a 10 is ten, or why they carry it over to the next column in the depth I now know how to do.

> There were a couple of times when I thought [she] understood a concept or was really firm in understanding a strategy. But when I would ask her similar questions, it would turn out that she was not really as sure as it had appeared. She could do it that time but it wasn't something she was really solid on. This happening a number of times made me aware of how you have to ask about the same concept in different ways to ensure a clear understanding of the interviewee's knowledge.

> I enjoyed the "bonding" during the interview and how much I could see the value in it for gaining understandings of how kids see math. I'm so caught up in "teaching" math. I can see how I've been missing the boat. Thinking about their thinking is the key to success for the child and the teacher. I also enjoyed it because it was nonthreatening and friendly—yet I learned a lot about what he knew. Tests make kids uptight—and you wouldn't get half as much out of it!

In the discussion of the full set of excerpts from teachers' journals, administrators noted that all the teachers were amazed that they could have taught all this time and never thought to ask the children about their thinking. They noted that when they had been teachers, they too had been oriented toward simply teaching the content. One said:

> We're taught what math is and how to teach it, and the strategies for teaching it, and never really think about the end product [i.e., what the students understand].

They noted that at least one of the teachers said that she was learning as well as the students, and

commented that this is something administrators sometimes forget. They talked about how teachers' continual learning connects to the shift in the role of teacher, from being didactic to being a facilitator, and how it is clear from the journal entries that the teachers were thinking about this shift in role. One administrator noted:

> In some ways . . . you begin to see a shift in how they see their role as teachers. That is, . . . there's a lot of talk about facilitating learning, about a different kind of role that they're going to play. And perhaps a different approach to what they do with kids.

And the administrators began to explore the implications for their own action when they considered the possibility that professional development for teachers might be based on listening to their mathematical and pedagogical ideas. As one administrator put it:

> This type of teacher reflection will cause a greater degree of introspection on the part of the teachers in order to . . . come to grips with what they do or *don't* know. . . . The implication that would have for teacher training is that you might not have to teach everybody all the same kind of thing—people might be able to do some self-diagnosis and figure out what it is they want to know more about. Because we always try to put people through a series of events and everybody may not need the same thing.

These administrators were beginning to see that listening to children's mathematical thinking could inform teaching and that teaching based on such listening would be a different kind of teaching. Further, the design of professional development for teachers would be similarly redefined if it were to be based on listening to **teachers'** mathematical and pedagogical thinking.

Layer 3: Listening Among Administrators. The final part of this session on listening provided an opportunity for administrators to get a taste of what it felt like to do one of these interviews, or be interviewed in this way. The purpose was not to understand each other's mathematical thinking in order to teach, but to appreciate the kind of intellectual work involved in listening in order to truly understand another's thinking and to see how the opportunity to articulate one's ideas can clarify one's own thinking (or uncover confusions).

In pairs, administrators interviewed each other on topics designed to provide them with the opportunity to learn about each other's thinking in areas related to mathematics education. Administrators were asked to listen carefully to each other's thinking and to try to understand it as thoroughly as possible. The purpose, they were told, was not for the interviewer to focus on whether she or he agreed or disagreed, or to tell of events in her or his own experience that confirmed or disconfirmed what the other had said. The purpose was to "put yourself inside the head of the other" and to look at the issue from his or her point of view. Administrators then discussed this experience. They discovered that the interviewee's train of thought might be quite different from their own and that it took real work to stay with the interviewee's thinking and explore it deeply. As one administrator described the role of interviewer,

> I found that I really had to pay attention to not asking questions about what interested me from what my interviewee was saying in answer to the question, but sticking with what she was saying and trying to frame questions that came from what she was saying in response to the question.

Another administrator/interviewer said,

> I was really focused and trying to go with him in the line of thought that he had, and my next question came from where he left off, not from a question that I had already prepared. . . . I was thinking very hard.

A third reported failure:

> I learned that I'm not a good interviewer. My questions lacked depth. I kept asking questions that were things of real interest to me. I wanted to hear ideas—things I could use. It was almost selfish, now that I look at it. Like, what are you doing with this, and kind of with an ear to, how can I use that back at my school. And so, I guess I'm a failure tonight.

One administrator/interviewee reported:

> She [the interviewer] was really listening carefully and responding with another question [from within my frame of reference.] And I had the experience that . . . I articulated some things

> that maybe I hadn't before. So I learned something [about my own thinking].

From this layered activity, the administrators learned about listening from the child's point of view, noticing how respectful it was to be listened to nonjudgmentally, how affirming it was to have someone be interested in what you think, and how much you can learn from the opportunity to explain your thinking. They also came to understand listening from the teacher's point of view and came to appreciate that when teachers are listening to children's mathematical thinking so as to understand what the child understands, they are engaged in arduous intellectual work.

These administrators were also struck by how useful it would be to listen in this way to teachers in their buildings and to administrative colleagues. Such listening would make a big difference in the culture and "feel" of schools, they felt. The systemic implications of the layered structure to this session were not lost on participants. As one administrator said,

> I love the way you structured the session—students, staff, us . . . I'd like to be able to use the architecture of the session in my own work with department heads—moving from classroom to school to system wide parallels in a process or problem.

Layering, as a pedagogical design strategy, appears to help administrators think about the way important values and norms of the mathematics education reform movement can extend beyond the classroom and come to characterize the profession of teaching and the intellectual culture of schools and districts more generally. It also connects a fundamental aspect of reformed mathematics instruction with a skill (active listening) that is often used by administrators in their administrative practice but that they may not have seen as related to the core of instruction itself (perhaps because the core of instruction had not involved listening). As the core ideas of instruction change, the way instruction aligns with management practice also changes and particular management skills may have new relevance. As one administrator put it,

> This is really wild! My wife is after me to listen better, and I take these courses in active listening that the district wants me to take. So, here I come to math class, where the answers are supposed to be cut and dried, and we're talking about listening!

Situating conceptual work in the consideration of practical action: The case of teacher supervision

When we began our work with administrators, our aim was to familiarize them with new ideas about mathematics, learning, and teaching so that they could help others—so that they could understand changes teachers were trying to make in their practice and provide appropriate supports. However, we quickly learned that focusing on topics that were salient in administrators' *own* work was far more effective. There, there were real puzzles for administrators to think through in order to know how to act on a daily basis. Focusing the discussion on issues in administrators' own work made the effort to rethink fundamental ideas seem worthwhile to them. There would be real consequences that mattered to them.

Among such functional arenas are supervising and evaluating teachers, understanding the criteria for good professional development for teachers, dealing with the impact of students' standardized test scores, and communicating about mathematics education reform with such stakeholders as parents and school boards. Each represents a compelling and problematic aspect of administrators' work for which the ideas embedded in mathematics education reform are significant. To do their work in each of these areas, administrators need to understand what mathematics education reform is fundamentally about and how the practical situation at hand might need to be understood in a new way. In the process of puzzling about these practical topics, administrators in our group were thinking through the implications of old and new ideas about math, learning, and teaching. They were "thinking in order to learn" (Thompson & Zeuli, 1997, p. 8)—that is, struggling to solve problems or resolve dissonances in order to come to a new understanding of the issues embedded in the task.

We focused most of our work with administrators on these functional areas. At their request, we devoted an entire year to thinking about classroom observation and teacher supervision; that work serves as the basis for this vignette.

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Teacher supervision is a powerful lever for change, lying precisely at the intersection between administrative practice and teacher practice. What supervisors see when they look at classrooms, what they think those classrooms should be, and what views they hold of the nature of their responsibility to both the teacher and the school system are central elements of supervision and very much affect what teachers are encouraged to do.

The history of ideas about teacher supervision parallels the history of ideas about the nature of learning and about how to ensure high-quality performance in organizations. What administrators see when they look at classrooms is shaped by prevailing views about the nature of mathematical knowledge, learning, and teaching (Bolin & Panaritis, 1992; Darling-Hammond & Sclan, 1992), and, relatedly, their views of the nature of the supervisory relationship with the teacher are shaped by prevailing views about what it means to assist teachers, and what it means to assess their practice (Rowan, 1990; Tracy, 1995). The current education reform effort provides a new turn to the kaleidoscope. New ideas about the nature of mathematics knowledge and what it means to learn (and teach) are resulting in classrooms that operate according to a new and different logic; new pedagogical ideas imply that supervision itself be interpreted as the facilitation of *teachers'* knowledge construction (Nolan & Francis, 1992).

All these issues were on the table for the administrators in our group. They knew that the standards for mathematics instruction were changing and that they needed to learn what good mathematics learning and teaching would now look like, if they were to do the work of teacher supervision. As we listened to their discussions about teacher supervision, it seemed that the pedagogy of the supervisory relationship was also an issue. When they observed classrooms, they tended to identify particular teaching problems and then give teachers advice (albeit often very indirectly) about how to solve those problems. One administrator described a typical scenario:

> So, you go to Mrs. Smith and start talking about, well, what are some strategies that you've used in the past that could be used? And you start brainstorming [together] and develop a list of strategies that would work for the kids. Then, the question is, the directive is, well, which of these do you think you might want to try? . . . So it's no longer [a discussion]. You've presented a choice.

Another administrator chimed in,

> In other words, you [the teacher] are going to change.

The pedagogical assumption that underlay the administrators' practice was that they were experts whose responsibility it was to identify teaching problems and get teachers to produce more effective teaching behaviors. This is very different from considering themselves to be the facilitators of teachers' ongoing construction of knowledge about mathematics, learning, and teaching. We expected that the pedagogical practices that supervisors would observe teachers using to help children construct rigorous mathematical knowledge in videotapes of reformed classrooms would raise this issue. (In this respect, the work on teacher supervision was layered—the same issue was considered at two organizational levels.)

In the year-long seminar on teacher supervision, our purposes were threefold: (1) to help administrators develop an eye for what reformed mathematics classrooms might look like, (2) to think with them about the pedagogical relationship between teacher and supervisor, and (3) to explore the characteristics of school culture that seemed to hinder or support the supervisory process. At each monthly session, we showed a 10-minute videotape of a classroom in which the teacher was in the process of transforming his or her mathematics instruction in accord with reform tenets.[2] At each session, administrators did and discussed the mathematics that would be presented in the lesson. They then viewed the videotape twice, the first time discussing the mathematics and the pedagogy of the lesson; the second time, discussing the kinds of things it would be important to talk about with the teacher and the pedagogy of the supervisor-teacher relationship.

Along the way, they learned many things. As they worked to understand what was happening in the classrooms on videotape, they began to question some of their former interpretations of the basic elements of instruction and to make

new interpretations. For example, administrators might formerly have thought it adequate to note that the mathematics topic being taught (e.g., multiplication of fractions) was in the curriculum and that the teacher had reached it at the appropriate time of year; over time, they began to attend to nuances and complexities in the students' ideas about multiplication of fractions.[3] They might earlier have thought it adequate to observe that the teacher asked questions of all students in the class evenhandedly; over time, they began to wonder whether the teachers' questions provided students with good opportunities to explore important mathematical ideas. (See Nelson & Sassi, 1998, for an analysis of how administrators' eye for elementary mathematics classrooms changed.)

They also began to reconceptualize the pedagogy of the supervisory relationship. As they viewed the videotapes and discussed how to have a discussion with the teacher after doing a classroom observation, we tried to build on their developing sense of the pedagogy of the mathematics classroom and encouraged them to consider the possibility that the supervisor might ask questions designed to stretch the teacher's thinking, rather than giving advice—thereby providing the teacher with the opportunity "to think in order to learn."

At one seminar, the administrators considered the effect of asking questions that would prompt reflection by teachers– what they came to call "bingo" questions. This episode illustrates the beginning of change in their ideas about the pedagogy of supervision. The excerpt from the transcript provided below shows four administrators and project staff exploring the likely effect of asking thought-provoking questions of teachers.

Susan Jones[4]: I think it really does matter the kinds of question that you raise. . . . There are so few opportunities for colloquy at all in the teaching profession that if the supervisor misses the opportunity to have an honest, authentic colloquy with the teachers, then that person's missed really a golden moment. And I think the question that's raised that weighs on somebody's mind is a wonderful thing. The question that makes you feel a little uncomfortable is a good thing.

MFT staff: So, you can imagine a question I could raise that nags at a teacher in a pretty useful, pretty wonderful way, . . . that they could . . . go home and have this nag at them productively. . . . How do you end up knowing that it's productive?

Ethel McGarry: Because we see change. Or they themselves [the teachers] come back and say, "You know, we talked about this a month ago. It's been bothering me. Can we talk about it because I'm thinking . . . you know, I've been thinking about this."

Jim Parker: Yeh, I think that's a good standard, actually, in terms of what you want to accomplish. It's authentic, that is, it's a real question, it's a meaningful question.

Susan Jones: If the principal or the supervisor, whoever it is, does that consistently, somebody's gonna say, "You know, you really asked a bingo question for me." But you cannot *not* use that time to raise those questions.

MFT staff: Sounds like you're saying that, over time, that kind of bingo question is really kind of respect for the teacher.

Steve Davenport: You know, I feel successful if the person re-engages me after one of those questions. . . . If you raise a question with somebody and . . . he or she comes to you over and over again, not in a defensive way but just in a "let's get this right." . . . It is a respectful piece. Because if you just say it was a good lesson and you walk out, they don't have a clue.

As a class exercise, the administrators developed several "bingo" questions that might be asked of a teacher on one of the videotapes they had

been watching—questions that would stretch that teacher's thinking. Several were questions about instructional moves the teacher had made, designed to encourage the teacher to be explicit about his or her mathematical or pedagogical reasoning. For example, the questions, "Why did you choose this particular pair of students to present their work? How did you decide who to pick?" would be asked not as though there were a correct answer that the supervisor knew but, rather, as the beginning of a mutually intriguing discussion about the mathematical ideas at play in the classroom and the pros and cons of highlighting this one or that one. Another question, "What would have happened if you had asked the kids to make multiple representations (i.e., using numbers, a drawing, manipulatives) of the way they were thinking about a mathematical problem?" would focus the teacher's attention on the range of representations she or he was typically providing and the effect that had on students' opportunity to think through mathematical problems. Like the questions that teachers now ask of students, these questions are open-ended, invite consideration of complex issues, and are chosen because thinking about them might be useful next steps for the students (or teachers).

In the ensuing weeks, the administrators went on to discuss the kinds of issues it might be important for teachers to think deeply about, the nature of the relationship between supervisor and teacher that would need to obtain for such question-posing to happen productively, and the character of the school environment that would support such open-ended inquiry about learning and teaching. But the notion of "bingo" questions marked the beginning of a change from the stance of advice-giving expert to the stance of facilitator of teachers' knowledge construction. Working out a new pedagogy for supervision provided these administrators with the opportunity to think through, in a practical domain with which they had regular experience, an important element of the new pedagogy that also underlay reformed mathematics classrooms.

Creating an analytic and reflective community among administrators

That classrooms should function as reflective communities for students and teachers is a hallmark of the mathematics education reform movement. Whether expressed in Standards and Frameworks that call for communication and discourse or in new mathematics curricula that advise teachers to ask students to explain their thinking, teachers are enjoined to have students discuss their ideas, listen to one another, and think critically about whether or not they agree with another student's thinking. Often teachers must work out for themselves how to do this (Lester, 1996).

The classroom as reflective community can also be easily misunderstood—for example, in the fear on the part of some that the right answer no longer appears to matter, so long as students can explain how they did the problem. If administrators are to support teachers and ensure educational quality and public understanding, it is important for them to understand why classroom inquiry and discourse are important and what the criteria are for good inquiry and discourse. However, if administrators are to develop a subtle and grounded sense of what an inquiry-based or discourse-based mathematics classroom is like, they need the opportunity to experience it for themselves, for, in general, their own mathematics education was not conducted in this way.

In most class sessions, we tried to do mathematics—the mathematics that would appear on a videotape, the mathematics that would appear in student work, the mathematics that would be in an article they read. While it was not possible to organize this mathematics to systematically cover the major ideas in the elementary mathematics curriculum, it was possible to conduct the mathematics part of our seminars much as teachers would conduct a reformed mathematics class. And so administrators had the opportunity to experience something of what it would be like to be in such a classroom, and they learned for themselves some of the behaviors necessary for such a classroom to work: respect for others' ideas; willingness to expose one's own, often tentative ideas to the scrutiny of others; subjecting ideas to principled examination in order to determine if they were correct.

This was an especially poignant experience for administrators who had not done any mathematics for many years and were not particularly confident of their mathematical abilities. Doing mathematics together at the beginning of every session was a real test of their ability to say what they thought clearly, even when they were unsure; to listen to each other seriously, searching for the sense that the other was trying to make; to not judge.

One evening, the group discussed angles in preparation for viewing the videotape of a classroom in which the students would be learning to measure the angles of a triangle with a protractor. Several figures were put on the board, and the administrators were asked which were angles:

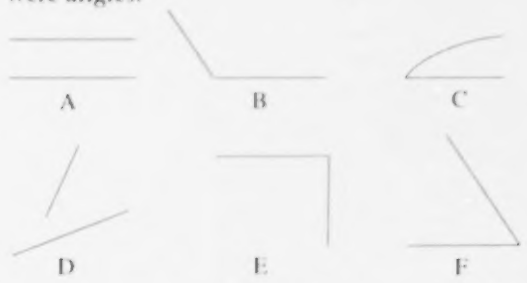

Figure 1

The consensus among all but the mathematics supervisor present was that B, C, E, and F were angles. When asked what properties they were looking for when they decided which ones were angles, several said they were looking for intersecting line segments. There ensued an extended discussion about Figure C and whether or not it could be said to be an angle.

Sylvia Pendell: The curved line isn't constant in its relationship to the lateral line.

MFT staff: And you're saying that makes it not an angle?

Sylvia Pendell: I don't know. It makes it many angles. At every point it's a different angle. Isn't it? Every point on the arc.

Ellen Christianson: C is a problem for me. . . . I named it as one of my angles and it's not because . . . I guess I would call that a potential angle, a kind of moving angle.

Sylvia Pendell: A dynamic angle.

Ellen Christianson: Thank you.

Joanne Smith: It's measurable, but you have to pick a point along that arc. If you pick a point along the arc [and construct a line to the vertex], then it becomes measurable.

Ellen Christianson: It's almost an infinite possibility.

C was a puzzling figure. It met the part of the definition of an angle that they could remember—intersecting line segments—but they hadn't seen an angle with a curved side before. They weren't sure enough about their memory of the definition of an angle to firmly exclude curved lines. However, they were willing to dig in and think it through. They listened thoughtfully to one another's ideas (it makes many angles; at every point, it makes a different angle), puzzled about what kind of sense those ideas made (there are infinite possibilities), and explored the implications (if you picked a point along the arc and constructed a line to the vertex, you could measure the angle). They were not afraid to suggest unorthodox ideas; they trusted one another enough to take even unorthodox ideas seriously and think them through; and they knew that, in the end, the mathematics had to make sense.

In general, the administrators' inquiry group was conducted as a reflective community of inquiry among participating administrators. Whether the group was discussing mathematics problems, a videotape of a mathematics classroom, or an assigned reading, interest in and respect for each other's ideas was established as a group norm. Over time, the administrators in the group developed a sense of what a reflective community was like and what it took to maintain it. As one administrator described it,

> I feel that we are intellectual colleagues here. I feel that we're kind of tacitly agreeing to deal with difficult questions in a very open way, here. And I think that's remarkable.

Another noted that it had taken a while for such a community to develop:

> It would be interesting to have someone join the group at this point, because over the last two years we really actually have grown into this relationship with each other. We certainly

> didn't start there. . . . It's more than just intellectual and, while we haven't visited each other, I think there's . . . been enough personal sharing and enough interaction that we really know each other in that professional sense.

And they saw both the relationship between reflection and action and the relationship between what they had been doing and what teachers might do.

One administrator noted:

> I think there's another part to [the] process that . . . is significant. . . . I see it in teachers in my school. This is the action part, that is, practice that is informed by reflection. There's a piece of this that is cyclical. Reflection and action and then reflection. And I think that teaching is strengthening to the degree that that's what we really are talking about.

Structuring the administrators' inquiry group so that it functioned as an analytic and reflective community gave these administrators the opportunity to experience important aspects of reformed mathematics classrooms—thinking hard about significant issues, showing respect for everyone's ideas, trusting that others would not judge or make fun of one's tentatively held ideas, and committing to support and investigate each other's thinking. It put them in the position to understand what the virtues of such classrooms might be and what it would take to make them work well.

It also raised issues for them about how administrative work in general was structured. Administrators' workdays are fragmented. For example, principals are physically on the move in their buildings for much of the day; their contacts with teachers, students, parents, and other administrators tend to be short; discussions are about current and pressing situations (Fullan, 1991). Central office administrators are often dealing with finances and politics, rather than educational issues (Fullan, 1991). Such work provides few opportunities for administrators to deliberate together about important educational issues. As one administrator put it,

> We do have these discussions but we don't have them in the places where we should. We don't validate those discussions and we don't have them and say, "These are an important part of our work places." People find informal ways to have these discussions . . . [but] we don't as an organization value them and, therefore, I think people keep these conversations outside the organization.

Listening and thinking together, rather than immediately moving to resolve issues, was hard for these administrators. This was particularly evident at one session, when an administrator talked with the group about the decision he had to make about whether a new teacher would get tenure. The group talked about how hard it had been for them to stick with the issues and not try to solve the problem:

> At times we were going through the process with Sam, and at times we ended up wanting to solve his problem for him. And I thought the conversation sort of seesawed back and forth, that way. It might be because it was such an emotional topic that we *wanted* to solve the problem for him, rather than think about Sam's process of going toward it, and giving him some reflections on *his* process.

Sam later said that he had valued the discussion because it provided him with a number of different lenses through which to examine his dilemma. "In fact," he said,

> for decisions of this magnitude you should *have* to go through that kind of reflective process, as a kind of check on your process, the ways in which we make our judgments. . . . So, I found it helpful—your probing and your questions—that asked me to think about what I meant . . . or what this process was.

The thoughtful reflection characteristic of reformed elementary mathematics classes stands in stark contrast to the generally frenetic and unreflective nature of school life, in which administrators engage in their work isolated from each other and without much opportunity for reflection or discussion. The administrators in our group valued the group itself for providing these opportunities and saw that their work, and the climate of their schools, would be improved if there could be more of it on an everyday basis.

Conclusions

Administrators are important actors in education reform, not solely because of their influence on school- and district-level policy but also because they enact, daily, a set of ideas about the nature of learning and teaching, thereby influencing the

intellectual culture of schools in particular ways. The ideas about mathematics, learning, and teaching that are embedded in the current mathematics education reform effort are complex and subtle, an interwoven web of assumptions, attitudes, and orientations that are quite different from business as usual in most schools. If we want these ideas to become a more prevalent part of American schooling, we need to learn more about what administrators themselves need to know about them, how they can come to learn about them, and, in turn, how they can reflect on and perhaps change their own administrative practice.

In the beginning of our work with school and district administrators, we perceived that there was often a misalignment between the ideas about learning, teaching, and mathematics that undergirded much of their administrative practice and the ideas about learning, teaching, and mathematics embedded in the mathematics education reform effort. Often administrators' practice was built on transmission ideas about learning and teaching and entailed assumptions about the standardization of student learning and the proceduralization of teaching practice. However, the ideas about learning, teaching, and mathematics that underlie the mathematics education reform movement are quite different. Now learning is seen as the process of thinking through puzzling and often difficult ideas, and teaching as providing resources and guidance for such thinking. Learners and teachers are viewed as being engaged in creative activities requiring judgment; classrooms are now the locus of intellectual debate and discussion that can stretch far beyond the classroom walls and the prescribed 42 minutes.

To help these administrators consider new ideas about mathematics, learning, and teaching and think about how such ideas might influence their administrative practice, we undertook to provide experiences that would give them the opportunity for fundamental conceptual change. This required finding ways to make the ideas embedded in mathematics education reform relevant to their own work, so that they would have the motivation to think through compelling and real problems in order to construct their own, situated knowledge of mathematics education reform. The three design principles described in this paper represent our effort to do this.

In the process, these administrators learned several substantive things about mathematics education: what it feels like to puzzle through a mathematical problem with others, and consequently, what both the certainty and the uncertainty of mathematical understanding feels like; how children's mathematical thinking develops; what teachers need to know and know how to do in order to support the development of children's mathematical thinking; what curricula, student assessment, teacher supervision, and communication with community stakeholders need to be if they are to support reformed mathematics instruction.

But the administrators also considered the possibility that embedded in mathematics education reform were norms and values that had implications for their own administrative practice. Examples discussed in this paper are listening respectfully to the thinking of another in order to truly understand what he or she means; learning to facilitate teachers' construction of their own knowledge about mathematics, children's learning, and instruction; and creating reflective and analytic communities for thinking through complex educational issues. Considering these raised questions about the nature of school administration itself and provided the opportunity for these administrators to think about how their own administrative practices could be connected more directly to the core of new instructional practice.

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Notes

[1]Elmore defines "the core of educational practice" as how teachers understand the nature of knowledge and the student's role in learning, and how these ideas about knowledge and learning are manifested in teaching and classwork. The "core" also includes structural arrangements of schools, assessment processes, etc. (Elmore, 1996).

[2]Many of these videotapes were produced by the Educational Technologies Department of Bolt Beranek and Newman, Inc., in a project entitled "Mathematical Inquiry Through Video: Tools for Professional Growth," directed by Ricky Carter and Fadia Harik and supported by the National Science Foundation.

[3]Students first develop their ideas about the basic arithmetic operations (addition, subtraction, multiplication, and division) in the domain of whole numbers. Later in their school years, they are introduced to a different kind of numbers—fractions. The basic operations may work differently on fractions than on whole numbers. For example, if one multiplies two whole numbers, the answer is larger than either of the original numbers. However, if the numbers are fractions, the answer is smaller. If students are to truly understand this and not just memorize the procedural rules for multiplication of fractions, they need to understand multiplication as being about numbers of "groups." So the question, What is 2 x 3? is asking, How many will you have if you have 2 groups (of 3 each)? The answer is 6. But the question, What is 1/2 x 1/3? is asking, How many will you have if you have 1/2 of a group (of 1/3 of something)? The answer is 1/6.

[4]Administrators' names are pseudonyms.

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